Microwave Assisted Amorphous Oxide Thin-Film Transistors with Polymer Gate Dielectrics

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ABSTRACT

In this work, a-IGZO TFTs were fabricated at room temperature by the synergistic combination of microwave annealing and polymer gate dielectrics. a-IGZO TFTs were successfully fabricated at room temperature and show good electrical properties and stability.

1 INTRODUCTION

Amorphous oxide semiconductors (AOSs) have attracted considerable attention as an active layer material for thin-film transistors (TFTs), due to their many advantages such as high field effect mobility and large area uniformity compared to amorphous Si counterparts [1]. In particular, amorphous indium gallium zinc oxide (a-IGZO) have widely been studied as high performance channel later for TFTs requiring high mobility, high on/off ratio, low leakage current and room temperature fabrication. Even if, a-IGZO TFTs can be deposited at room temperature, additional thermal treatment is still required in order to obtain satisfactory electrical characteristic and stability [2].

As electrical properties strongly depend on the dielectric/channel interface, dielectrics are another key material to operate TFTs. SiN_x and SiO_x are commonly used dielectric materials for TFTs, where PECVD method has been widely used for fabricating them. In order to obtain high quality dielectric layers, PECVD process generally requires high temperature which is not suitable for flexible substrates with low glass transition temperature [3-4]. Therefore, to realize flexible TFTs with cost-effectiveness, low temperature process is strongly required for gate insulator growth and AOS activation.

In this work, a-IGZO TFTs were fabricated at room temperature by the synergistic combination of microwave annealing and polymer gate dielectrics. Microwave radiation was applied in air ambient at room temperature to replace conventional thermal annealing. On the other hand, parylene-c, as a polymer-based dielectric layer which shows a strong chemical stability and high dielectric strength was deposited by pyrolysis-CVD system at room temperature.

2 EXPERIMENT

Figure 1 shows the schematic cross-section image of fabricated top gate a-IGZO TFTs. The glass was used as a substrate after an ultrasonic cleaning process. 30 nm-thick a-IGZO active layer was deposited by radio frequency (rf) magnetron sputtering process using a 3-inch IGZO target having the composition of In:Ga:Zn = 1:1:1 at%. Microwave annealing was performed at a power and frequency of 600 W and 2.45 GHz, respectively. After microwave treatment, 10 nm-thick titanium (Ti) and 150 nm-thick aluminum (Al) was deposited by thermal evaporation system as source and drain electrodes.

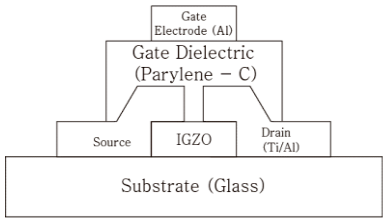

Fig. 1. Schematic cross-section image of a-IGZO TFT fabricated by microwave annealing and polymer gate dielectrics at room temperature

Figure 2 shows the schematic image of fabricating process of parylene – c polymer dielectric at room temperature using pyrolysis chemical vapor deposition (CVD) system. The parylene – c was adopted as dielectric material due to its strong chemical stability and room temperature fabrication. Parylene –c was deposited by pyrolysis CVD at temperature of 5°C. Finally, 100 nm-thick Al were fabricated by thermal evaporation system as a gate electrode. All patterns were defined by shadow mask. The channel width and length of the IGZO TFTs were 800 and 200 μm, respectively. Overall process temperature is under 40°C

3 RESULTS & DISCUSSION

Figure 3 show the ellipsometry spectra of parylene – c thin film by ellipsometry analysis. Refractive index and extinction coefficient of parylene – c films were obtained as a function of wavelength in the range from 200 to 1000 nm. Both refractive index and extinction coefficient have peak at around 210 nm, then decrease. The refractive index and extinction coefficient at 600 nm is 1.650 and 0, respectively. This is well-matched with previous reported parylene – c thin film [5].

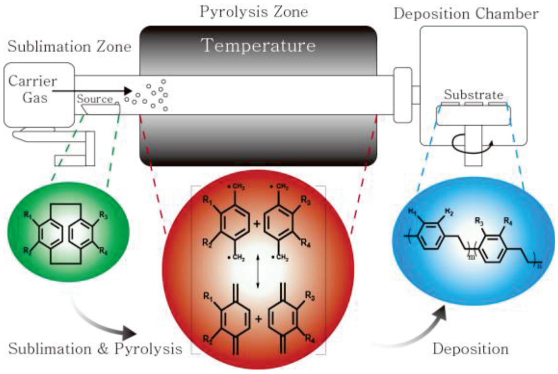

Fig. 2. Schematic image of deposit parylene – c film via pyrolysis chemical vapor deposition system

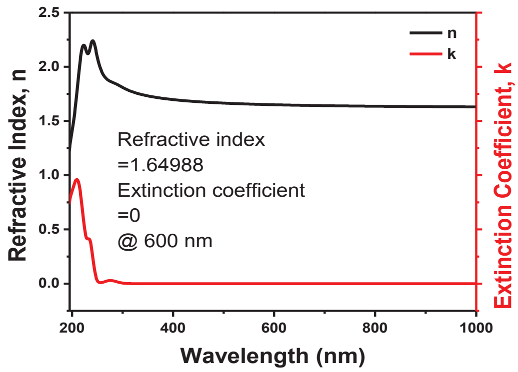

Fig. 3. Ellipsometry analysis of parylene – c film as a function of wavelength

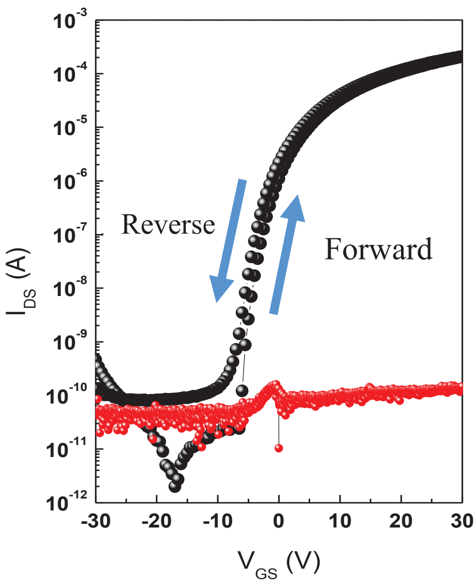

Fig. 4. Transfer characteristics of a-IGZO TFTs fabricated by microwave annealing and polymer gate dielectric

Figure 4 show electrical characteristics of a-IGZO TFTs fabricated by combination of microwave annealing and polymer dielectric. The transfer curve was measured in the saturation regime with drain voltage (V_D) of 10 V and the gate voltage (V_G) was swept from -30 to 30 V and then back to -30 V to evaluate the hysteresis characteristics. Table 1 consist of the representative parameters such as saturation field effect mobility (μ_{sat}), subthreshold swing (SS), threshold voltage (V_{th}), on/off current ratio (I_{on}/I_{off}), and hysteresis voltage. a-IGZO TFT exhibit μ_{sat}, SS, V_{th}, I_{on}/I_{off} and hysteresis voltage of 14.62 cm^2/Vs, 0.45 V/dec, 5.85 V, 10^7, and 1.1 V, respectively. Also, leakage current of a-IGZO devices show very small, indicating that room temperature fabricated parylene – c has good insulating properties.

Table. 1 Electrical properties of a-IGZO TFTs

Saturation mobility	Subthreshold swing	I_{on}/I_{off}	Threhold voltage	Hysteresis voltage
14.62 cm^2/Vs	0.45 V/dec	10^7	5.85 V	1.1 V

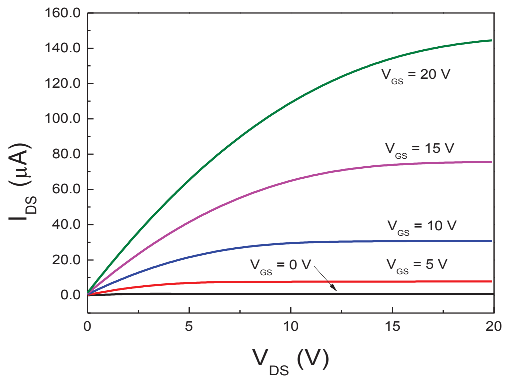

Fig. 5. Output characteristics of the a-IGZO TFTs with microwave annealing and polymer gate dielectric

Output curves shown in Figure 5 were measured at V_D = 0 to 20 V and V_G = 0 to 20 V in interval of 5 V. The device well operates in n-channel characteristics with low drain current at zero gate voltage. Because the channel of IGZO layer is formed in the positive gate voltage region, linearly increasing drain current is observed at low gate voltage and exhibits current saturation and pinch-off at higher voltage region. Due to ohmic-like contact and no current crowding, a-IGZO TFTs with fully room temperature fabrication have good output characteristics.

To evaluate the stability of a-IGZO TFTs, positive bias stress (PBS) and negative bias stress (NBS) tests were conducted. Applied V_G and V_D were -20 V and 0.1 for NBS and 20 V and 0.1 for PBS, respectively. Each test was conducted in air at room temperature for 1hr. For the PBS test, a-IGZO TFTs undergo positive V_{th} shift of 0.87 V. While a-IGZO TFT conducted on NBS shows positive V_{th} shift of 0.23 V. This indicate that microwave annealing can successfully remove structure defect and rearrange structure of IGZO. Also, this indicate that there are few traps in interface between IGZO active layer and parylene – c gate dielectrics.

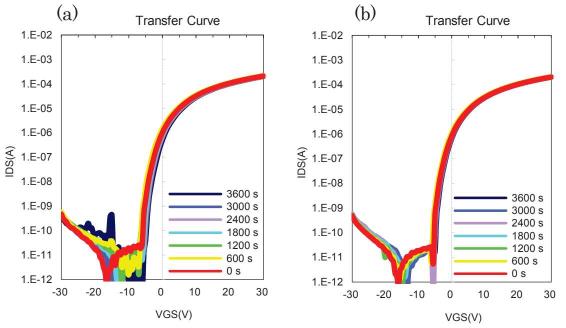

Fig. 6. Variation of the transfer curves under (a) positive bias stress, (b) negative bias stress

4 CONCLUSIONS

In this work, a-IGZO TFTs fabricated by combination of microwave annealing and polymer gate dielectrics were demonstrated. Room temperature fabricated a-IGZO TFT has good electrical performance with a saturation mobility of 14.62 cm^2/Vs, SS about 0.45 V/dec, V_{th} of 5.85 V, I_{on}/I_{off} ratio of 10^7 and hysteresis volatege of 1.1 V. In addition, the devices showed good PBS and NBS stability V_{th} shift of under 1V.

5 Reference

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